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FORESTS FOR THE FUTURE[1]

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This discussion pertains to the future productivity and management of the commercial forest lands of the ten western states, the area extending from the eastern borders of Montana, Wyoming, Colorado, and New Mexico to the Pacific Ocean. Commercial forest land is defined as "forest land bearing or capable of bearing timber of commercial character and economically available now or prospectively for commercial use and not otherwise withdrawn from such use" (1). Noncommercial forest land is chiefly valuable for purposes other than timber production. Since its management differs markedly from that of commercial forest land, it lies outside the scope of this paper.

The western states contain some 108 million acres of commercial forest land, mostly in Montana, Idaho, Washington, Oregon, and California (2). These lands bear 98 per cent of the nation's virgin timber. The western forests are notable for the presence of such commercially valuable species as Douglas fir (*Pseudotsuga menziesii* (Mirb.) Franco), ponderosa pine (*Pinus ponderosa* Laws), sugar pine (*Pinus lambertiana* Dougl.), western white pine (*Pinus monticola* Dougl.), and redwood (*Sequoia sempervirens* (D. Don) Endl.), not one of which occurs elsewhere in the United States. Some of these forests, notably the Douglas fir, spruce-hemlock, and redwood types of western Washington, Oregon, and northwestern California, have growth rates probably equal to any in the northern hemisphere. In contrast, some forests of the ponderosa pine type that occur in localities having low precipitation grow very slowly, but if allowed to mature for several centuries produce timber of high value. About two thirds of the western commercial forest area is in public ownership, mostly federal. The privately owned lands, constituting those selected out of the public domain prior to the establishment of the national forests, are generally more accessible and productive.

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The commercial forests of the West are currently producing nearly 40 per cent of the nation's sawtimber, and timber production is, of course, one of their principal uses. The other values inherent in these forests, however, are of critical importance to the West, and must be given due weight in management practices. I refer primarily to water yield and the production of forage that provides grazing, mostly during the summer season, to substantial numbers of domestic livestock. The use of commercial forests for recreation, including hunting and fishing, does not basically affect management practices.

The principal tasks that lie ahead in making the western commercial forests fully productive of timber can be grouped under four general objectives: protection; conversion of virgin forests into well-stocked growing stands; prompt establishment of adequate regeneration; and improvement in quality and yield of wood.

The first objective, protection, is designed to decrease losses from fire, insects, and disease. The western forests suffer an annual loss of more than one billion board feet of timber from these causes. About one fourth is due to fire, and three fourths to insects and disease. This loss can never be entirely prevented, but it can be materially reduced.

Reduction of fire losses will be achieved by fire prevention, largely through public education; increase in specialized, highly skilled personnel; development of improved equipment; and aggressive research upon the nature of and relationships between the ground and atmospheric conditions affecting forest fire.

Progress is being made in reduction of losses from parasitic insects. New, powerful insecticides, applied to large forest areas by airplane, are proving increasingly efficaceous in controlling certain types of insects. Other types are being attacked by silvicultural methods providing environments favorable to tree vigor and unfavorable to the insects.

The struggle to decrease losses from the many fungus diseases attacking the forest is seemingly never ending. Losses caused by wood-rotting fungi are often heavy in virgin forests containing a large proportion of old trees. As these virgin forests give way to young, vigorous stands of second-growth timber this type of damage will decrease. Silvicultural methods seem promising for the control of some diseases attacking juvenile trees.

A new approach, the genetic development of tree forms resistant to insects and fungi, is now assuming importance. Current research is giving encouraging results.

Attainment of the second objective, conversion of virgin forests into well-stocked, growing stands, is necessary to assure permanent production of wood products. Only a system of forestry which provides for the growing and harvesting of successive timber crops can guarantee a continuous timber supply. The virgin forest is a natural heritage of great value. To the commercial forester, however, it can only be considered as the current crop of timber, to be harvested and replaced by the man-cultured young forest that will, when mature, constitute the next timber crop. In commercial forestry the tree farm will supplant the forest primeval. It is recognized, of course, that areas of virgin forest required for scientific study and for recreation will be reserved and are then, by definition, no longer considered as commercial forest.

Effective conversion of a virgin forest into a vigorous, well-stocked second-growth stand is a vexatious and difficult matter. Methods of harvesting the virgin timber have markedly different effects upon the amount of regeneration and the promptness of its appearance. The relative merits of clear cutting and selective cutting of virgin stands are frequently debated by foresters. Both doubtless have their place in the western forests. In the dense stands of the Douglas fir and spruce-hemlock types in western Oregon and Washington, clear cutting in small enough blocks to assure adequate seed dispersal from surrounding trees is proving effective. In many of the thinner ponderosa pine forests, where every acre may bear trees from seedling size to merchantable veterans, selective cutting often proves more advantageous.

To secure the third objective, prompt establishment of adequate regeneration on cut-over areas and in poorly stocked juvenile stands, is a difficult task at best in many parts of the West. A substantial portion of the western commercial forest area is characterized by high temperatures and scanty precipitation during much of the growing season. These conditions militate against the establishment of sufficient numbers of coniferous seedlings to form an adequate stand. The density of many virgin forests indicates that in the past nature has coped with the problem successfully. But nature is content to spend many decades in developing a dense forest; man is not. Many of our best virgin forests may well have resulted from a fortuitous sequence of such favorable circumstances as the sudden destruction of an old forest by fire during the late summer of a good seed year, followed by a year of temperatures and summer precipitation particularly favorable to the establishment and survival of forest tree seedlings. But commercial forestry cannot await the operation of so uncertain a process, so other ways must be found to secure prompt regeneration.

Planting, as a solution to the problem of uncertain natural regeneration, has been only partially successful in the West, because adverse field conditions affect planted tree stock and natural seedlings alike. Also, it is a costly process. Nevertheless, it has certain advantages over natural regeneration. Where successful, it assures a stand of the desired species, with the trees properly spaced to produce high yield at maturity. And it is only by planting that trees genetically improved by breeding can come into use.

It is probable that forest planting in the West could be much more successful, despite adverse field conditions. Study of the methods commonly used in seed collection, nursery growing of the planting stock, and its outplanting in the field leads me to the conclusion that practices consistent with the principles of the plant sciences are frequently sacrificed in order to keep costs at a minimum. The cost accountant seems able to outvote the plant scientist in determining procedures. Analyses of current planting methods by plant scientists and more research on problems not yet solved would, I am sure, materially increase the degree of success of planting.

Direct seeding, in contrast to the planting of nursery grown stock, offers some promise for artificial regeneration. Two methods are being tested: broadcasting of seed from airplanes and planting of the seed at regularly spaced intervals. The greatest deterrent to either method is the presence of rodents that eat the seeds or the seedlings. Temporary heavy reduction of the rodent population on the seeded area by the broadcasting of poison bait may be the answer to this problem.

The fourth objective, improvement in quality and yield of wood, opens up new and interesting possibilities in forestry. It holds the promise of increasing timber production by application of the same scientific knowledge that has increased farm crop production so markedly. There are two possibilities: tree improvement for greater yield and better quality, and soil improvement for greater yield.

In the United States, forest tree improvement is a new and rapidly developing field of research from which material benefits can be expected. Its object is the development of tree forms specially suited to local conditions, including resistance to the insect and fungus pests of the particular region; good form and growth rate; and special wood qualities designed to meet the requirements of special uses. Two general methods of forest tree improvement are being used: selection of superior races and phenotypes, and development of new forms by breeding.

Provenance studies, by which races of widely distributed species are tested under a variety of environmental conditions, are useful tools in selection of races and are being widely used. In most cases a race is better suited to its own environment than to any other, but tests have demonstrated valuable exceptions.

A practical method for selection of superior phenotypes is by securing seed from groups of superior trees, carefully selected for desired characteristics and sufficiently isolated to prevent cross-pollination from other, poorer forms. This can be accomplished by harvesting or roguing out the inferior trees on an area containing a goodly number of superior individuals and by removal of all trees of the same species over a surrounding area of sufficient size to effect the necessary isolation. Cross-pollination thus occurs only between superior trees.

Increasing evidence indicates that the continued, persistent selection of superior races and phenotypes will bring a degree of improvement of forest growing stock that justifies its application to forestry. While admittedly slow, improvement is cumulative in effect. Selection has the advantage of simplicity in comparison with tree breeding and can be applied by foresters who do not have specialized knowledge of plant genetics.

Forest tree breeding, however, holds the greater potentiality for forest tree improvement. Forest trees are one of the few widely used kinds of plants which have not been materially improved by genetical means, and the potentialities for their improvement are as great as those for any of our agricultural crops. Over the past century a number of natural forest tree hybrids were described and a few artificial hybrids were produced, but no attempt was made to apply the information to practical forestry. It is only in the last two decades that forest genetics has been recognized as a distinct branch of plant genetics, with its own objectives, methods, and increasing body of literature.

In the United States, breeding work on many forest tree species is now being conducted by numerous universities and by federal, state, and private research institutions. The work is largely exploratory in nature, in that very few artificially bred tree forms are old enough to permit evaluation at maturity. A large number of hybrids are being produced, mostly interspecific, but with an increasing number of intraspecific crosses between well-defined races of several species. Some of these new forms indicate in the juvenile stage that desirable traits of the parents can be brought together in the F_1 generation. A few hybrids indicate true heterosis with attending advantages of rapid growth. A number of the more promising hybrids are now undergoing large-scale field tests, generally in the form of comparison with the parent species. The breeding work is developing better knowledge of species relationships within several important genera, which will facilitate future development of new forms.

One of the greatest needs is for more research of a fundamental nature to provide tree breeders with information which will make their work more effective. Physiological and genetical studies of vegetative reproduction, flowering, growth, and wood structure of forest trees, and evaluation and measurement of the range of genetic variability of important timber species and their races are examples. Recent and valuable work by Pauley and Perry on ecotypic variation (3) and Mirov on the gum turpentines of pines, discussed in more detail later, are examples of the kind of research needed.

In the western states most of the work in forest tree breeding has been conducted by a single organization, the Institute of Forest Genetics at Placerville, California, a branch of the California Forest and Range Experiment Station, U.S. Forest Service. The Institute has made no attempt to cover the entire field of forest tree improvement, but has limited its work to breeding and related studies of species within the genus *Pinus*, one of the most important and valuable genera in the West. This specialization has brought notable progress within its narrow field. There remains, however, the need for work on other genera.

The Institute's principal work has been the production of pine hybrids. Since the inception of its breeding program in 1927, some 67 pine hybrids have been developed. Several exhibit marked heterosis, a phenomenon seemingly most apt to appear in the product obtained by crossing two closely related species of widely separated occurrence. An example is the hybrid *P. monticola* Dougl. × *P. strobus* L., which greatly exceeds either parent in growth. Another hybrid, thus far exhibiting satisfactory form and growth rate, seems to possess the very high resistance of one parent to a specific insect parasite. This hybrid, *P. jeffryi* Grev. & Balf. × *P. Coulteri* D. Don, has the commercially desirable form of *P. jeffryi,* is superior in growth to that parent, and evidently possesses the extreme resistance of *P. coulteri* to the reproduction weevil, *Cylindrocopturus eatoni* Buch., a destructive parasite occurring on young trees of several pine species, including *P. jeffryi.* The hybrid of *P. strobus,* susceptible to white pine blister rust, *Cronartium ribicola* Fischer, and of *P. griffithii* McClelland, highly resistant to the rust, has undergone seven years of exposure to the disease with no evidence of infection. These examples are indicative of the progress possible through specialization of forest tree breeding to a single genus.

The Institute's investigation of the chemistry of gum turpentines of pines, conducted by Dr. N. T. Mirov, has proved to be of special value. The study has included the turpentines of most of the pine species of the world for which previous analyses were not available, and analyses for the species of the United States and Canada are now practically complete (4). It has been found that the turpentine content of any species, or in some cases of a well-defined race, is uniform, irrespective of environmental conditions. Hybrid species contain all of the turpentines of both parents, but in other proportions. The resistance of the hybrid *P. jeffryi* × *P. Coulteri* to the reproduction weevil is seemingly associated with the presence of an oleoresin originally occurring in the resistant *P. Coulteri* and absent in the susceptible *P. jeffryi.* Further, the degree of resistance appears to be related to the amount of the oleoresin in the hybrid form, as indicated by the fact that the F_1 hybrid, containing more of the oleoresin, is more resistant, and the back cross onto *P. jeffryi,* containing less of oleoresin, is less resistant. These facts justify the hypothesis that the oleoresin is the cause of the resistance. Classification of pine species based upon their turpentines provides a better basis for determining species crossability than taxonomic systems based upon macroscopic plant characters (5). These results from the study of gum turpentines illustrate the value of fundamental research to provide the tree breeder with information basic to his work.

The yield of timber from a forest crop is directly related to the fertility of the soil upon which it grows. The possibilities of increasing the yield on poor soils are limited. The need for soil protection and soil improvement will become more evident as forest geneticists develop faster growing tree forms that will make severe demands upon the supply of plant nutrients available in the soil.

Forest soils can become impoverished and, in fact, can be made unsuitable for forest tree growth in several ways. Repeated, severe forest fires will adversely affect the structure, physical condition, and chemical and biological nature of forest soils. They will cease to possess the combination of properties by which we characterize forest soils. Natural processes, involving the recapture of the site by arborescent vegetation, will finally reestablish the forest, but a long period of time is often necessary.

Comparable damage to forest soil can result from practices causing topsoil losses by erosion. Logging and road construction on steep slopes, particularly when accompanied by almost complete destruction of the vegetative cover, often cause heavy erosion. A degree of soil disturbance that merely loosens and cultivates the topsoil without heavy erosion may favor forest regeneration. But disturbance that results in exposure of heavy, compacted subsoil makes regeneration difficult.

Forest soil improvement has hardly progressed beyond the stage of theory in the United States. We have not as yet accepted the idea that soil fertilization is physically or economically practicable, except in cropland soils. Progress in forest soil fertilization in other countries will, I hope, stimulate research here. In Australia application of phosphates to forest soils has resulted in an increase of tree growth that may make the practice economically desirable, and application of small amounts of zinc to Monterey pine seedlings has brought astonishing results (6). Research on fertilization of western forest soils, including determination of its economic feasibility, is a new and open field of study. Many forest soils in the West are deficient in nitrogen and phosphorus, and little is known of the effect of adding these elements. Also, a study of micro-element deficiency might bring results of practical value.

The water demands of the West, to meet the increasing domestic, industrial, and agricultural needs of the growing population, are constantly expanding. The commercial forest areas, together with the high mountains, are the source of this water. No matter how far it must be transported to meet the needs of population centers, its invariable sources are the mountainous areas of high precipitation. Forest management, therefore, must do its share to maintain and, if possible, augment water yield.

In a thoughtful and informative paper, Dr. E. A. Colman (7) recognizes three ways by which forest management can contribute to water yield: protection, repair, and improvement of forested watersheds. Protective measures are designed to maintain a favorable water flow and low erosion rate equal to those of the virgin forest. They include fire protection; careful location, construction, and maintenance of roads; and the use of logging methods least damaging to the structure of the forest floor, the surface accumulation of organic matter above the mineral soil.

Repair of damaged watersheds consists of such measures as immediate revegetation, preferably with valuable forest species, of forest lands denuded by fire; prevention of erosion on denuded lands by construction of small dams; soil stabilization on areas disturbed by logging; and clearing of stream channels choked with logging debris.

To quote Dr. Colman, "The objectives of water yield improvement are to reduce streamflow in winter and early spring when supplies are greater than needs, increase the low flows of the dry season when water is in short supply, and decrease evaporative water losses in ways that will increase the quantity of usable water available downstream." Past experiments indicate that the desired regulation of streamflow may be accomplished by timber harvesting methods favorably affecting snowpack, consequent rate of snowmelt, and direct evaporation of water from snow. A recent experiment in Colorado indicates the value of timber cutting in some pattern of strips or blocks that lessens the tree crown surface of the forest, thereby permitting more snow to reach the ground, yet providing the most possible shade. The effect is to decrease snow evaporation in the tree crowns and to retard, by shading, the rate of snowmelt on the ground. Similar experiments are needed in other parts of the West where other conditions exist.

Of the 17½ million acres of commercial forest land in California, some 10 million acres, or 57 per cent, produce forage utilized by domestic livestock, game animals, or both, and some such proportion probably holds for all of the western states. Some of this area has permanent grazing value but most of it can be grazed only during limited periods in each forest rotation. A substantial part of the forage occurs in the open meadows frequently found in the forest. Wherever occurring, forest forage must be protected from over-grazing, and depleted ranges must be repaired, in order that soil losses, destructive to timber, water yield and forage alike, may be prevented.

There is at present widespread feeling that western forest management practices for timber, water, and forage production differ so greatly that they are in serious conflict. If, however, their mutual interest in common objectives is weighed against their differences, I see no basis for real conflict. All three call for protection from fire, except where used under control as a tool of resource management, and from other destructive forces. All recognize the need for prevention of accelerated erosion and loss of topsoil, and for prompt revegetation of denuded areas. In all cases, sound management practices to attain these ends will, perforce, be based upon the economically feasible application of the plant and soil sciences and other disciplines such as hydrology and climatology. Recognition of this broad area of common interest will relegate conflict to the level of differences which can be settled by adjustment.

Predicted increases in the population of the western states will make demands upon the commercial forests of the region which will justify a more intensive degree of management than is now being practiced. Much more knowledge than is at present available will be needed, and many difficult problems will have to be solved. All that can now be said is that no end to the development of forest management practices can be foreseen. As new technologies develop new products, the kinds of raw materials needed from the forest may change, with consequent changes in management objectives. The quest for knowledge to meet increasing demands for forest products, old or new, will require an expanding and continuing research effort in which western universities and other research institutions will have an important part. The combination of continued research and conservative management will maintain throughout the future the productivity of the western forests.

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